We are IntechOpen, the world's leading publisher of Open Access books
Built by scientists, for scientists

6

Luminescence Dating as Comparative Data to Radiocarbon Age Estimation of Morasko Spherical Depressions

Wojciech T.J. Stankowski[1] and Andrzej Bluszcz[2]
[1]Institute of Geology, Adam Mickiewicz University, Poznań,
[2]Institute of Physics, Silesian University of Technology, Gliwice
Poland

1. Introduction

In the areas of glacial relief there are numerous small symmetrical endorheic depressions, the genesis of which is almost always described as cryogenic – melt-out, evorsive or post-periglacial. Occasionally different origin of these forms is described, such as karst or suffosive, while very rarely it is associated with impacts. Interpretation of the genesis of the latter is very difficult and requires specialized testing methods, among which the luminescence techniques seem to be very promising. They allow the authors not only to argument for the existence of an impact, i.e. the reset caused by temperature and pressure, but also the dating of the event.

The Morasko Meteorite Nature Reserve is one of very few places on the globe where, besides numerous lumps of metallic meteorites, the existence of impact craters was documented (Phot. 2, 3). There are serious arguments supporting this idea, although the genesis of these depressions is still controversial and some authors attribute it to cryogenic or impact origin (Hurnik 1976, Karczewski, 1976, Kuźmiński 1976, Stankowski 2009).

The elevations of Moraska Hill show glacitectonic structures which include Quaternary sediments of various age and the so-called Poznań clays from Neogene. Significant complexity of these structures means that the age of the rocks in the bottom of the Morasko depressions is from several million to ~18,000 years BP (Stankowski, 2009). This last date is a good reference point for radiocarbon dating of organic deposits as well as verifying luminescence dating of mineral fractions subjected to pressure and temperature of the falling meteorites.

The current state of knowledge regarding the age of glacial relief and the time of permafrost degradation in the analyzed area (Ołtuszewski 1957, Kozarski 1963, 1986, Makohonienko 1991, Tobolski 1991), clearly differs from the beginning of the sedentation in the Morasko depression (Tobolski 1976, Stankowski 2009) – see Fig. 1. This should be considered as one of the important indicators of the genesis of the controversial depressions which call into question their cryogenic origin.

2. Radiocarbon dating of the bottom layers of the organic deposits in the Morasko craters and peat sequences with metallic spherules in the melt-out depressions in the vicinity of Oborniki

Shallowly buried metallic meteorites, constantly found in the area of the Morasko Meteorite Nature Reserve and its vicinity, indicate their local fall. The results of the studies undertaken in the 1970s (Hurnik et al. 1976) show the north trajectory of the fall. Information about finding two small lumps of metal in the Obornickie Forests, which were lost during World War II, together with the results of the work of Hurnik and other authors (1976) formed the basis of the search for magnetic matter in peat filling the melt-out depressions and in organic and carbonate sediments that occur in the valleys of the Warta River tributaries (Fig. 2). Complementary data were obtained regarding the age of the peat sequence containing the admixture of fine-grained magnetic material as well as the age of the bottom layers of organic deposits which fill the Morasko depressions. This compliance is well documented by the results of the radiocarbon datings (see Fig. 1 and 2).

The initial series of datings was carried out at the Radiocarbon Laboratory of the Institute of Physics, Silesian University of Technology (A. Pazdur). The samples from individual depressions were of very diverse age. The earliest dates are 2.7 ka and 3.4 ka BP (see Fig. 1 – craters B and E). The samples were taken from the pilot drilling with light hand equipment in winter and posed the starting point for further specialized research.

Radiocarbon dating and the verifying luminescence analyses were performed on the drill cores from the two largest Morasko depressions – MOA with a diameter of about 90 m and MOB with a diameter of about 50 m (see Phot. 1). The cores were collected with the use of the equipment from GeoForshungZentrum from Potsdam thanks to the kindness of J. Negendank and the work conducted by M. Shwab. The radiocarbon datings were performed at the Poznań Radiocarbon Laboratory by T. Goslar - the calibration program OxCal v3.10 was employed (see Bronk 2001). The luminescence dating was realized in the Gliwice Luminescence dating Laboratory by A. Bluszcz.

The MOA profile, the depression permanently filled with water of ~1.5 to ~2.5 m deep.

- 0.000 – 0.250 m various peat from well preserved to fully decomposed with wood fragments and gyttja-like thin layers
- 0.250 – 0.290 m moss peat of diverse density; plant macrofossils fully recognizable; stratification visible through the section
- 14C dates - peat 20 cm above the bottom: 4,465±35 (Poz-18864); peat 3-5 cm above the bottom: 4,495±35(Poz-18863; 4,980-5,300 cal. BP)
- 0.290 – 0.295 m gyttja-like sediments

Very sharp boundary of Neogene/Quatrenary sediments in between peat and Neogene clays thin strata indicating almost immediate sedentation beginning after the origin of the depression

- 0.295 – 0.298 m silt with small quantity of sand
- 0.298 – deformed Neogene clays ("Poznań series")

The MOB profile, the depression permanently filled with water of ~0.4 to ~1.5 m deep.

- 0.000 – 0.385 m various peat from well preserved to fully decomposed with wood fragments and gyttja-like thin layers
- 0.385 – 0.390 m strongly decomposed peat/organic matter, slightly stratified
- 0.390 – 0.405 m decomposed peat with visible plant fragments and pieces of wood
- 0.405 – 0.407 m very dense, well decomposed peat containing some silty sand 14C date, peat 3-5 cm above the bottom: 4,760±40(Poz-18960; 5,320-5,600 cal. BP)

Very sharp boundary of Quaternary mineral and organic sediments

2-3 mm layer of dark greyish-brown fine sand.

- 0.407 – 0.447 m horizontally stratified silty, sandy, clayey sediments
- 0.447 – 0.472 m clay mixed with fine sand
- 0.472 – 0.672 m sand from fine to coarse with disperse organic matter
- 0.672 – Quaternary and Neogene sediments (clays, tills and gravels). The luminescence data obtained from the uppermost part of mineral sediments (~3-4 cm) beneath the organic matter – see results below.

Radiocarbon datings of organic sediments filling the Morasko depressions clearly indicate the young age of the early sedimentation – see dates 4,495±35 and 4,760±40 in above sections describe. Indirectly, this shows the time taken to generate the depressions, which is a few thousand years different from degradation of the permafrost and melting of buried dead ice masses in this part of the Wielkopolska/Great Poland Lowland Region (Kozarski 1963; compare also Fig. 1). This validates the view of the impact genesis of the analyzed forms – craters. The role of verification is seen in the luminescence analyses (Stankowski, 2011).

3. Luminescence data confirming a young, impact genesis of the Morasko depressions

Two approaches to luminescence analyses were used.

1. The first one was to determine the luminescence reset time due to the fall and plunge of hot lumps of meteorites into the sediments, which resulted in the creation of their sinter-weathering shells. The TL datings of four meteorite shells of the specimen weighing 10.5 kg, 11 kg, 21 kg and 164 kg, were realized by S. Fedorowicz from the Institute of Geography, University of Gdansk (Stankowski et al 2007, Stankowski 2009, 2011).

The dating results were similar, from 4.7 to 6.1 ka BP, corresponding with the previous palynological findings on the sedentation origins as well as the verifying radiometric data. The obtained TL values, indicating the reset time, document the local nature of the meteoritic shower in Morasko, and indirectly confirm the impact origin of the depressions, i.e. that they were generated in the form of craters.

2. The second issue was to find the reset scale of local Quaternary and Neogene sediments, which build the elevations of Morasko Hill. The above description of the geological profiles of the craters bottom layers indicate significant differences in the age of sediments – from the youngest, i.e. ~18,000 years BP and of glacial and fluvioglacial origin, to the advanced in age, i.e. the Neogene clays being at least several million years old. The age of the significant part of the deposits, and perhaps of the majority of them, should exceed the range of the luminescence dating.

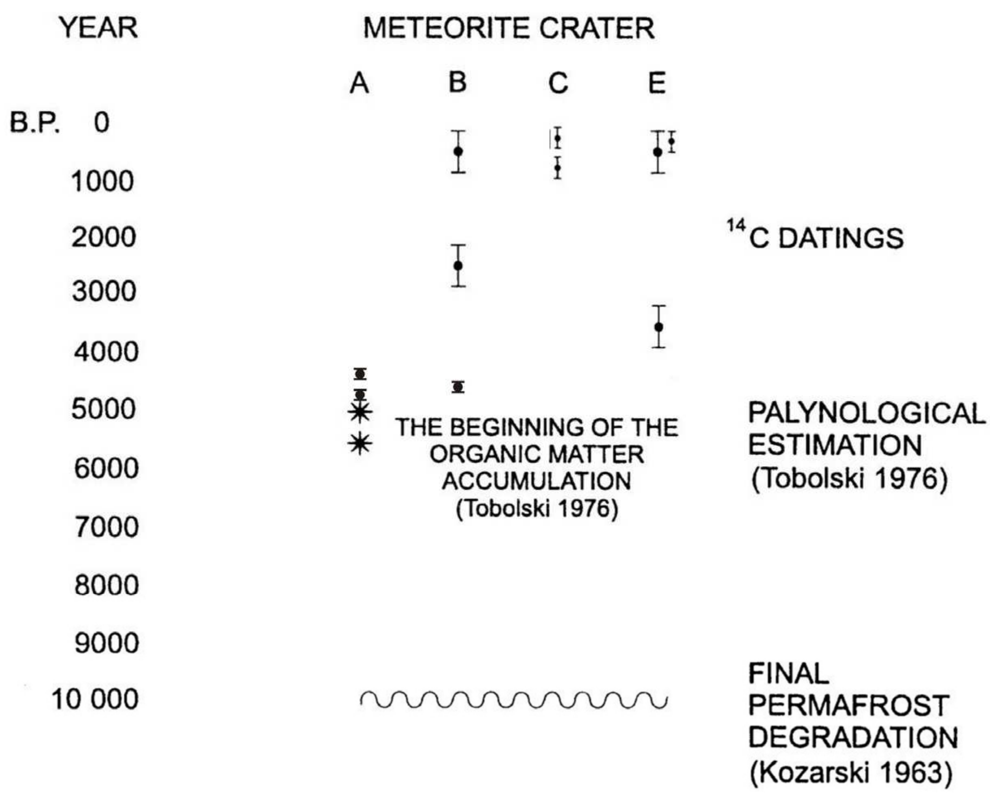


Fig. 1. Morasko depressions and their surroundings – radiometric dating, palynologically estimated beginning of sedentation, degradation of permafrost in the Wielkopolska/Great Poland Lowland Region.

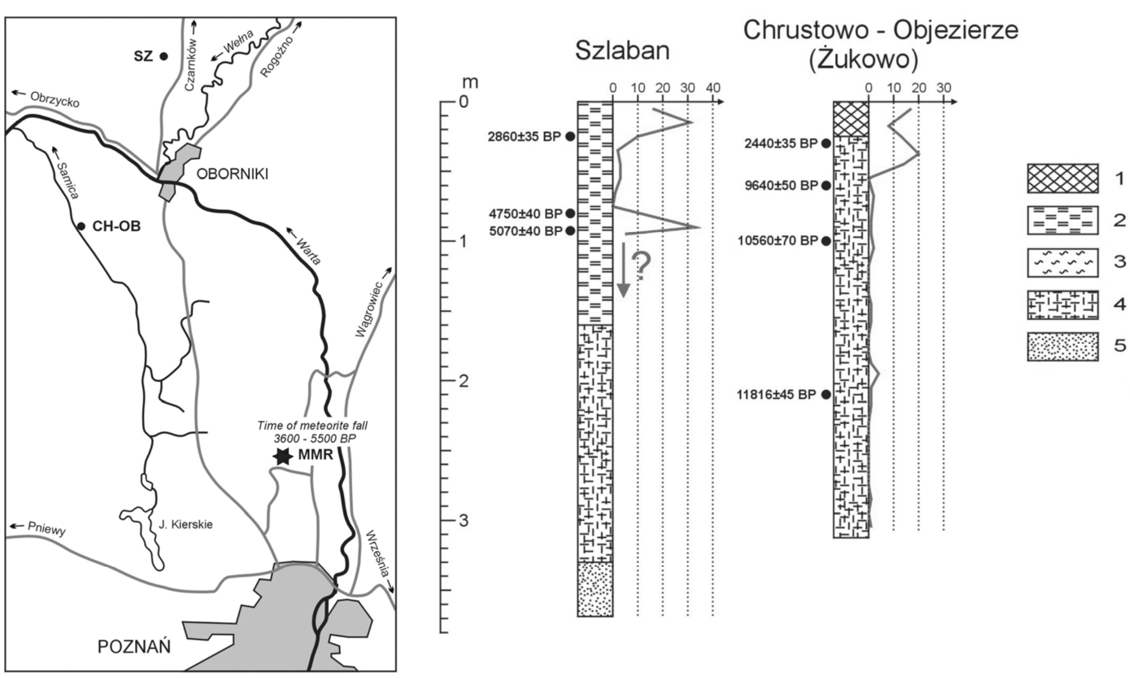


Fig. 2. Morasko Meteorite Nature Reserve (MMR) and its northern belt. Simplified geological profiles of the Szlaban and Chrustowo-Objezierze sites, with the 14C dates and indicators of content of small spherical magnetic fraction (spherules). 1) soil humus layer, 2) pea, 3) gyttja, 4) organic-rich silty muds, 5) sands with fine gravel.

The original unpublished results of luminescence dating in OSL technique obtained by A. Bluszcz (laboratory numbers for MOA crater GdTL-1328 through GdTL-1332 and for MOB crater GdTL-1333 through GdTL-1336), indicate the existence of a reset, but with varying extent. This is illustrated by the sets of luminescence measurements for the sediment samples from the bottoms of the both analyzed craters (Fig. 3, Fig. 4).

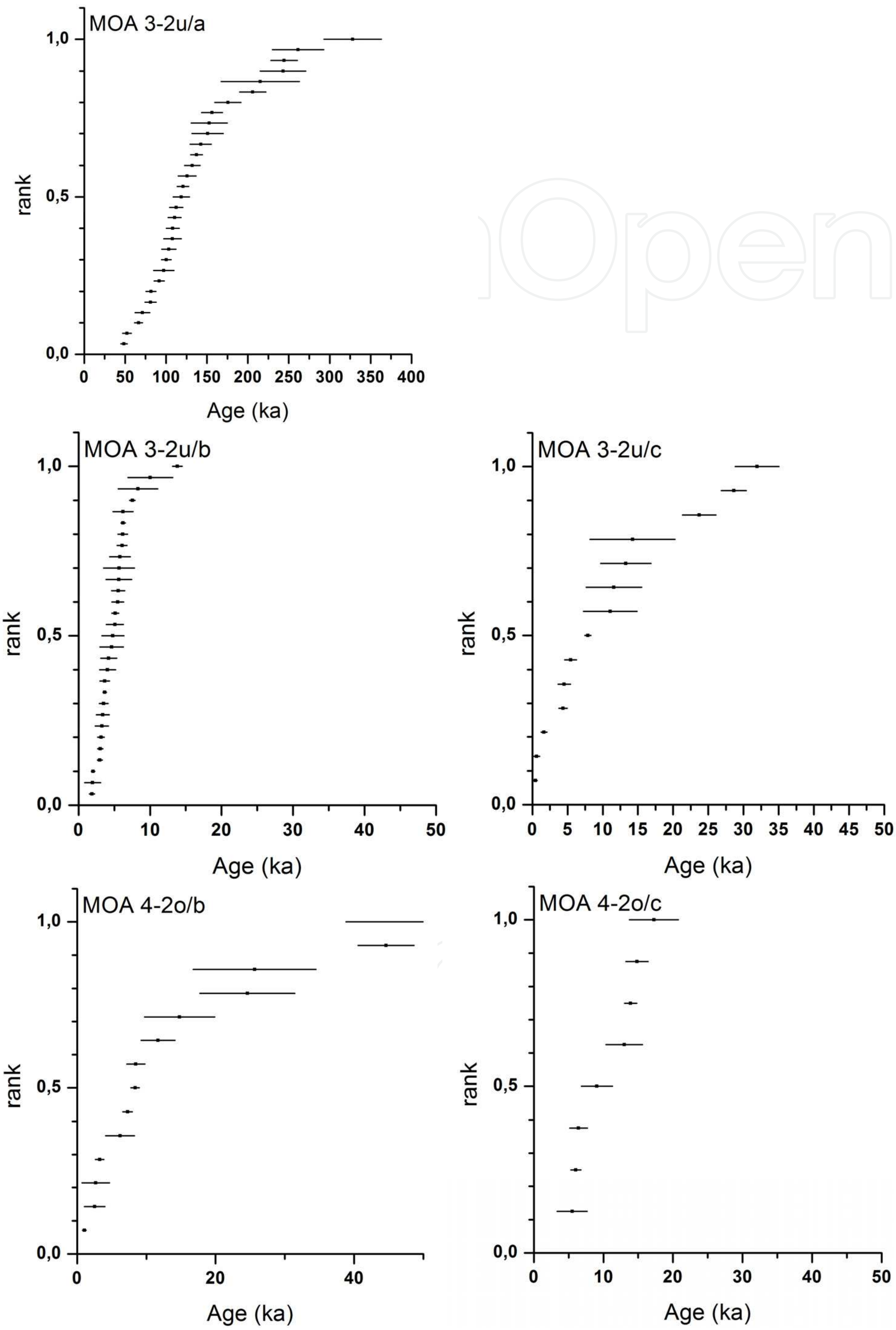
The results of the instrumental measurements in the bottom of the main craters shows the Fig. 3 and Fig. 4, with the containing tables.

Among the measured samples of sediments from the bottom of largest crater – MOA, build of the mineral Neogene deposits (Fig. 3), considerable variation of indicators can be observed. The collection of the oldest dates shows the range of the age from ~350,000 to ~45,000 years BP. A large number of indicators range from ~30,000 to ~10,000 years BP. Among the obtained data there are also many with the values lower than 10,000 years BP, with a significant proportion of them dated at <5,000 years BP. A statistically significant separateness of the ranges of measurement errors is worth mentioning. With respect to the young age indicators, the range of error turns out to be much lower. Thus, the mandated presumption is that, besides the nature of the measurement, it also stems from the effect of the reset range, potentially various in terms of pressure and temperature of a falling meteorite. Disproportionately low rates of the documented age of the sediments, in relation to their Neogene origin, prove very recent resetting. This rejuvenation, and especially the significant representation of the dates below 10,000 years BP, seems to justify the reset time of the deposits, and therefore the time when the Morasko Meteorite fell.

In the bottom of the second largest Morasko crater, MOB, Quaternary deposits are present. According to the authors these sediments are older than the last glacial period, at an age over ~130,000 years (the depression bottom is developed in sediments much older than the last glacial ones). The obtained age indicators of the 35 measured samples of deposits are much younger (Fig. 4). Only in particular cases they fall within the range from ~45,000. Other indicators did not exceed 27,000 years BP, with a significant proportion of the dates of <10,000 years BP. Occasionally, there are dates younger than 5,000 years BP. This range of dating seems to confirm the suggestion that the initial age of the studied sediments is older than the last glaciation, while the resetting time is younger.

The bottoms of the two analyzed craters are built of the sediments which are lithologically diverse and of very different age. According to the authors they originated more than 130,000 years BP. However, in relation to the earliest morphogenetic glacial processes, which potentially generate sediments, it is even possible to accept ~18,000 years BP, i.e. the time of the Leszno and Poznań phase of the last glaciation.

Taking into account the possible role of permafrost degradation and the time of the final melting of dead ice masses, we can theoretically go back to 11,000-10,000 years BP. Thus, the obtained indicators of luminescence age should only exceed this theoretical turning point. Meanwhile, both the Neogene clays and Quaternary sediments are often represented by very young luminescence ages. Approximately 47% of all the datings show indicators <10,000 years BP, among which ~19% are indicators of <5,000 years BP (compare Stankowski 2011). This indicates a very early time of luminescence resetting. The presence of older age indicators shows that resetting during the impact was characterized by a diverse range of completeness.


MOA 3-2u/a
rank
1,0
0,5
0,0
0 50 100 150 200 250 300 350 400
Age (ka)
MOA 3-2u/b
rank
1,0
0,5
0,0
0 10 20 30 40 50
Age (ka)
MOA 3-2u/c
rank
1,0
0,5
0,0
0 5 10 15 20 25 30 35 40 45 50
Age (ka)
MOA 4-2o/b
rank
1,0
0,5
0,0
0 20 40
Age (ka)
MOA 4-2o/c
rank
1,0
0,5
0,0
0 10 20 30 40 50
Age (ka)

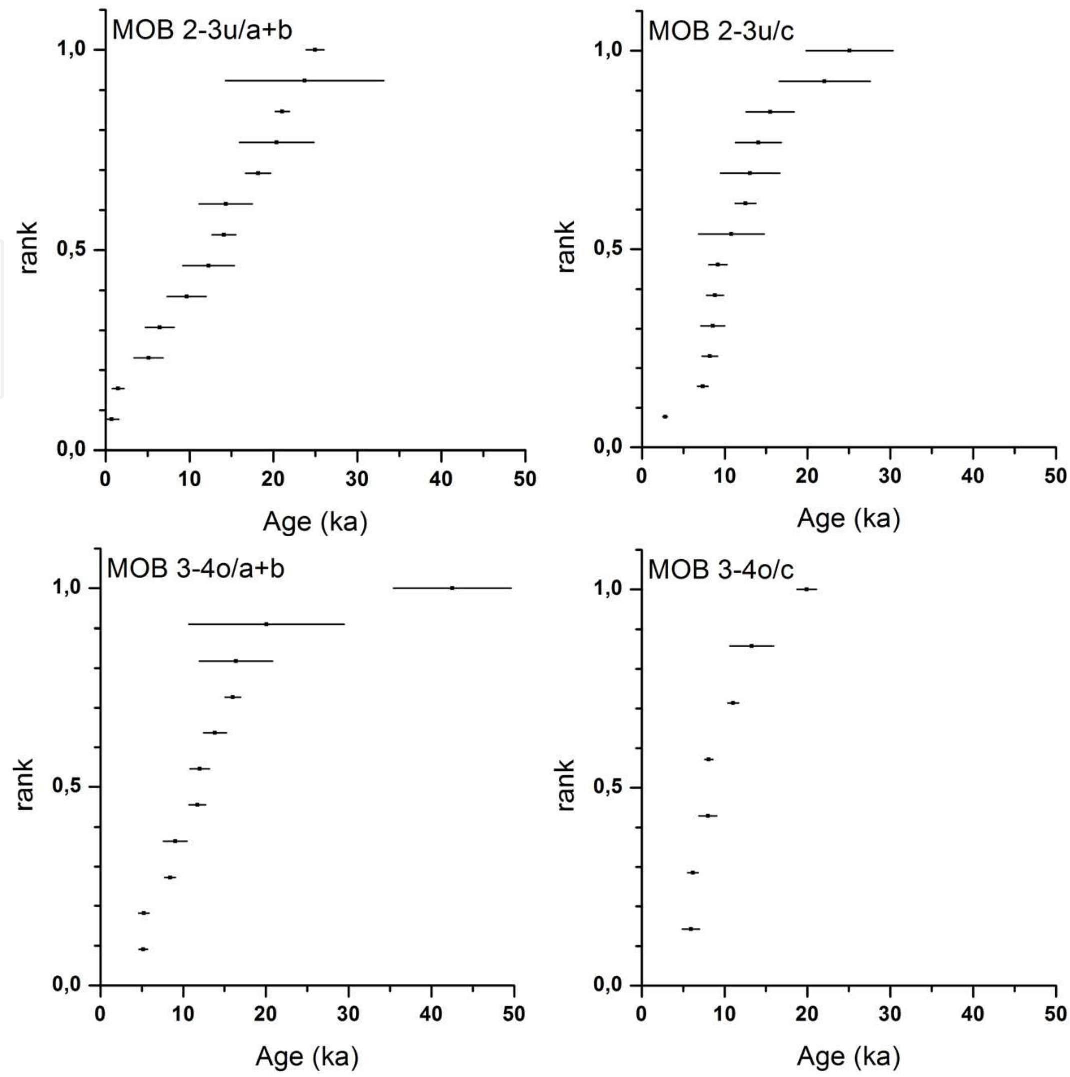
Single aliquot OSL dating results (ka) for MOA samples

GdTL	MOA 3-2u/a 1328		MOA 3-2u/b 1329		MOA 3-2u/c 1330		MOA 4-2o/b 1331		MOA 4-2o/c 1332	
	Age	u(Age)	Age	u(Age)	Age	u(Age)	Age	u(Age)	Age	u(Age)
1	48,6	3,8	1,87	0,34	0,45	0,23	1,04	0,25	5,5	2,2
2	52,2	5,4	2,0	1,1	0,60	0,43	2,5	1,5	6,04	0,73
3	66,4	4,8	2,02	0,16	1,65	0,41	2,7	2,0	6,4	1,3
4	71,2	8,9	2,97	0,32	4,37	0,57	3,25	0,61	9,1	2,2
5	81,2	6,9	3,04	0,35	4,52	0,87	6,2	2,1	13,0	2,6
6	81,6	6,0	3,14	0,46	5,42	0,84	7,28	0,68	13,90	0,87
7	91,5	6,2	3,26	0,91	7,90	0,42	8,37	0,59	14,8	1,6
8	97	12	3,39	0,89	11,1	3,8	8,5	1,3	17,3	3,5
9	100,3	6,0	3,51	0,61	11,6	3,9	11,7	2,4		
10	103,5	8,7	3,66	0,16	13,3	3,6	14,8	5,1		
11	108	11	3,66	0,67	14,2	6,0	24,6	6,8		
12	108,1	8,0	4,1	1,1	23,7	2,4	25,6	8,9		
13	110,5	7,9	4,2	1,1	28,6	1,8	44,6	4,0		
14	112,4	8,2	4,6	1,6	31,9	3,1	51	12		
15	118,5	9,9	4,8	1,5						
16	120,7	7,0	5,1	1,2						
17	126	11	5,12	0,47						
18	132,1	9,6	5,49	0,81						
19	137,3	7,1	5,55	0,91						
20	142	13	5,6	1,8						
21	151	19	5,7	2,2						
22	153	22	5,8	1,4						
23	156	13	6,09	0,69						
24	176	16	6,17	0,66						
25	206	16	6,22	0,29						
26	215	48	6,2	1,4						
27	243	28	7,52	0,37						
28	244	16	8,3	2,7						
29	261	31	10,0	3,1						
30	328	35	13,82	0,67						

Other information

Sample	MOA 3-2u/a	MOA 3-2u/b	MOA 3-2u/c	MOA 4-2o/b	MOA 4-2o/c
Laboratory number	GdTL-1328	GdTL-1329	GdTL-1330	GdTL-1331	GdTL-1332
Number of aliquots dated	44	54	54	47	29
Acceptable dating results	30	30	14	14	8

Fig. 3. Indicators of the luminescence ages for the samples from the top layer of the Neogene clays in the bottom of the crater A (MOA). The horizontal scale – luminescence age indicator, vertical scale – cumulative frequency or rank. Some aliquots have not yielded a result when the absorbed dose could not be calculated from SAR measurements, and some calculated dose values have not been accepted when the assessed uncertainties were too high (high values of uncertainties are caused by weak OSL signals) or when an aliquot does not pass a recuperation test or a sensitivity correction test (Bluszcz, 2000).



Single aliquot OSL dating results (ka) for MOB samples

GdTL	MOB 2-3u/a+b 1333		MOB 2-3u/c 1334		MOB 3-4o/a+b 1335		MOB 3-4o/c 1336	
	Age	u(Age)	Age	u(Age)	Age	u(Age)	Age	u(Age)
1	0,70	0,86	2,80	0,25	5,17	0,52	5,9	1,0
2	1,48	0,71	7,35	0,62	5,24	0,62	6,18	0,64
3	5,1	1,7	8,19	0,95	8,42	0,64	8,0	1,1
4	6,5	1,7	8,5	1,4	9,0	1,4	8,09	0,49
5	9,7	2,3	8,8	1,0	11,71	0,99	11,04	0,64
6	12,3	3,1	9,2	1,1	12,0	1,2	13,3	2,6
7	14,1	1,4	10,8	4,0	13,8	1,4	19,9	1,2
8	14,3	3,2	12,5	1,2	15,99	0,94		
9	18,2	1,5	13,1	3,6	16,4	4,4		
10	20,4	4,4	14,1	2,8	20,1	9,4		
11	21,04	0,84	15,5	2,9	42,5	7,1		
12	23,7	9,4	22,1	5,5				
13	25,0	1,0	25,1	5,2				

Other information

Sample	MOB 2-3u/a+b	MOB 2-3u/c	MOB 3-4o/a+b	MOB 3-4o/c
Laboratory number	GdTL-1333	GdTL-1334	GdTL-1335	GdTL-1336
Number of aliquots dated	44	40	39	34
Acceptable dating results	13	13	11	7

Fig. 4. Indicators of the luminescence ages for the samples from the top layer of the Quaternary deposits in the bottom of the crater B (MOB). The horizontal scale – luminescence age indicator, vertical scale – cumulative frequency or rank. Some aliquots have not yielded a result when the absorbed dose could not be calculated from SAR measurements, and some calculated dose values have not been accepted when the assessed uncertainties were too high (high values of uncertainties are caused by weak OSL signals) or when an aliquot does not pass a recuperation test or a sensitivity correction test (Bluszcz, 2000).

Photo 1. Morasko crater B (second in size) – obtaining cores from the bottom sediments. GeoForshungsZentrum equipment.

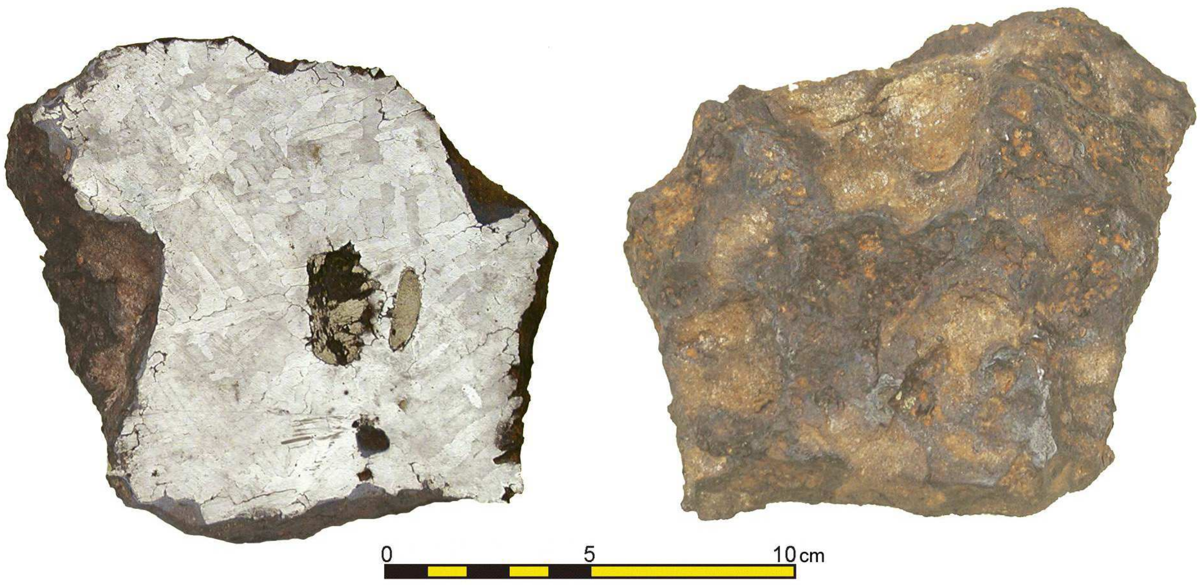


Photo 2. Fragment of meteorite of 7,5 kg found near crater C (third in size)

Photo 3. Meteorite of 164 kg found at the top part of southern fragment of the ringwall of crater A (main crater)

4. Summary

The results of the luminescence dating of the origin of the sinter-weathering shells, i.e. the resetting during the fall of the meteorite and its sinking into the sediments, were confirmed in the resetting of the material currently present in the bottoms of the depressions, i.e. the sediments were not moved from its original position and possible portions of the material gravitationally displaced from the slopes. This should be seen as a support of the concept of the impact origin of the analyzed forms. In the newly-created craters conditions for fast sedentation occurred. This is documented by the radiocarbon dating of the bottom layers of the organic deposits. Luminescence dating provided the verifying data of the genesis of the Morasko crates in relation to the previous radiocarbon and palynological estimations. The impact connected with the generation of craters took place in Mroasko ~5,000 years BP.

5. Acknowledgements

This study was possible thanks to the cooperation of many people, to whom we owe sincere thanks. We direct them to Prof. J. Negendank, PhD M. Schwab, from GeoForshungsZentrum in Potsdam, Prof. A. Pazdur from the Institute of Physics, Silesian University of Technology, Prof. T. Goslar from the Poznań Radiocarbon Laboratory, Prof. S. Fedorowicz from the Institute of Geography, University of Gdansk, as well as Prof. A. Raukasa from the University of Tallinn, for numerous constructive consultations.

6. References

Bluszcz A., 2000: Luminescence dating of Quaternary sediments – Theory, Limitations, Inetrpretations Problems (in Polish). Zeszyty Naukowe Politechniki Śląskiej, Geocgronometria 17 (seria Matematyka-Fizyka z. 86) 104 pp.

Bronk Ramsey C., 2001: Development of the radiocarbon calibration program OxCal. Radiocarbon, 43(2A), 355-363

Hurnik H., 1976: Meteorite „Morasko" and the region of the fall of the meteorite W: Meteorite Morasko and region of its fall. Wyd. Nauk UAM, Poznań 3-6

Hurnik H., Korpikiewicz H., Kuźmiński H., 1976: Distribution of the meteoritic and meteor dust In the region of the fall of the meteorite „Morasko". W: Meteorite Morasko and region of its fall. Wyd. Nauk UAM, Poznań 27-37

Karczewski A., 1076: Morphology and lithology of closen depression area located on the north slope of Morasko Hill near Poznań. W: Meteorite Morasko and region of its fall. Wyd. Nauk UAM, Poznań, 7-19

Karwowski Ł., Muszyński A.,: Multimineral Inclusions in the Morasko Coarse Octahedrite. 71st Meeting of the Meteoritical Society: Abstracts A71, 5232

Kozarski S., 1963: O późnoglacjalnym zaniku martwego lodu w Wielkopolsce (Late-Glacial Disappearance of Dead Ice In Western Great Poland – summary). Bad. Fizjogr. Nad Polską Zach., 11. PTPN, Poznań, 51-59

Kozarski S., 1986: Skale czasu a rytm zdarzeń geomorfologicznych vistulianu na Niżu Polskim (Timescales and the Rhythm of Vistulian Geomorphic Events In the Polish Lowland – summary). Czasom. Geogr., 57, Wrocław-Warszawa, 247-270

Kuźminski H., 1976: Dynamic element of the meteoritic shower "Morasko". W: Meteorite Morasko and region of its fall. Wyd. Nauk UAM, Poznań 45-63

Luecke W., Muszyński A., Berner Z., 2006: Trace element partitioning In ten Morasko meteorite from Poznań, Poland. Chemie der Erde 66 (2006), 315-318

Makohonienko M., 1991: Materiały do postglacjalnej historii roślinności okolic Lednicy (Beiträge zur postglazialen Vegetationsgeschichte In Lednica-Gebiet – zusammenfassung). Część II – Badania palinologiczne osadów Jeziora Lednickiego – rdzeń I/86 i Wal/87 (Palynologische Undersuchungen von Sedimenten des Lednicer Sees – Bohrherne I/86 und Wal/87 – zusammenfassung), W: Dotychczasowy stan badań palinologicznych i biostratygraficznych Lednickiego Parku Krajobrazowego. Biblioteka Studiów Lednickich, Wstęp do paleoekologii Lednickiego parku Krajobrazowego (red. K. Tobolski/ Introduction to Palaeoecology of the Lednica Landscape Park/Einführung in die Paläoökologie des Lednicer Landschaftsparks, Wyd. Nauk. UAM, Poznań, 63-86

Stankowski W.T.J., Raukas A., Bluszcz A., Fedorowicz St., 2007: Luminescencje dating of the Morasko (Poland), Kaali, Ilumetsa, Tsoorikmae (Estonia) meteorite craters. Geochronometria, 28, 25-29

Stankowski W., 2009: Meteoryt Morasko osobliwość obszary Poznania/ Morasko Meteorite, a curiosity of the Poznań region. Wyd. Nauk. UAM, Poznań, ss.92

Stankowski W.T.J., 2011: Luminescence and Radiocarbon Dating as Tools for the Recognition of Exstraterrestrial Impacts. Geochronometria 38, z. 1, 50-54

Tobolski K., 1976: Palynological investigations of bottom sediments In closed depressions. W: Meteorite Morasko and region of its fall. Wyd. Nauk UAM, Poznań, 21-26

Tobolski K., 1991(red): Dotychczasowy stan badań palinologicznych i biostratygraficznych Lednickiego Parku Krajobrazowego (Gegenwärtiger stand der paläobotanischen und biostratigraphischen Forschungen In Lednicer Landschaftspark – zusammenfassung). Biblioteka Studiów Lednickich, Wstęp do paleoekologii Lednickiego parku Krajobrazowego (red. K. Tobolski / Introduction to Palaeoecology of the Lednica Landscape Park/Einführung in die Paläoökologie des Lednicer Landschaftsparks, Wyd. Nauk. UAM, Poznań, 11-34